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INNOVATION IN CIVIL ENGINEERING
ИНОВАЦИИ В СТРОИТЕЛНОТО ИНЖЕНЕРСТВО

PLENARY SESSION

LEVEL 6 BUILDING INFORMATION MODELLING (BIM) CIVIL ENGINEERING CURRICULUM

Robert Eadie

[1]School of the Built Environment, Ulster University, Shore Road, Newtownabbey, UK
r.eadie@ulster.ac.uk

Mark Rice

Graham Construction, Devon, England, UK

Abstract. *Building Information Modelling (BIM) teaching has been added to the curriculum of Civil Engineering courses in the United Kingdom relatively recently. The BIM Academic Forum reported in 2013 on a general way to implement BIM teaching. Further work specified Level 6 topics. However, the importance of each of these topics in relation to the structures and highways disciplines was not fully researched. This paper e-xamines, from a BAF perspective, the topics and their importance to the specialisms. It shows that all BIM topics are more important to students specialising in structures than those in highways. It further indicates that both streams need to concentrate on BIM roles, BIM data maturity principles, and Collaboration tools. Big Data can be mentioned but can be minimised.*

Keywords: *Building Information Modelling; Disadvantages; BIM Implementation; BIM interoperability*

1. Introduction

Building Information Modeling (BIM) has been made mandatory in the UK from April 2016, through the UK Government Construction Strategy [1]. This has resulted in hasty incorporation of BIM across many Higher Education Institutions (HEI's). The BIM Academic Forum (BAF) was founded in 2011 to produce a standard set of guidance and provide consistency in BIM adoption across these HEIs [2]. The main task of the BAF was the development of a '*BIM academic framework*'; the outcome was the production of a *Learning Outcome Framework (2013)* [3]. This Framework is not discipline specific. However, it allows HEI's flexibility to implement it in a 'discipline-specific' undergraduate and postgraduate manner.

1.1 Embedding BIM in the Curriculum

The BAF (2013a) [3] cite previous used work by Williams and Lees (2009) to determine the impact of infusing or embedding BIM into the curriculum for the

following elements: the BIM descriptor, Curriculum, Structure, Staff, Infrastructure and Curriculum research gap.

1.2 Civil Engineering Strands at Ulster

Ulster University has two major strengths in research which feed into the Bachelor of Engineering BEng (Hons) Civil Engineering Course and the strands on the Master of Civil Engineering (MEng) Course: Structures and Highways.

The structures element focuses on fire research, with the fire laboratory (Fire SERT) the second biggest in the UK. Fire SERT's state-of-the-art facilities have produced the Euro code Design for Composite Floor Cellular Steel Beams in Fire [4].

The Highways element aligns with the research into skid resistance and photogrammetry that the University has produced over the last number of years aligned with Formula 1.

Students on the BEng(Hons) Civil Engineering complete the final year at level 6 Bachelor (Honours) Level, which is the penultimate year for MEng students. Therefore BIM teaching at this level must enable these students to complete the specialisms at level 7 Master of Engineering.

1.3 Linking Level 6 Subjects to the Curriculum

Ulster University has implemented BIM but has also been carrying out research into the topics needing covered and how it is delivered from a pedagogical standpoint. Previous work by McLernon et al (2014) [5] suggested the following BIM related topics need to be taught in final year Bachelor of Engineering and Bachelor of Science (Level 6). These are: -

1. Productivity improvements from BIM
2. Service diversification as a result of BIM
3. BIM Case study evidence from early adopters
4. BIM Roles (BIM Execution Plans, Roles, Responsibilities, Zoning Strategy, Federation, Deliverables, Data Drops)
5. Big Data – informing design – evidence based design
6. Sustainable Construction Principles + Carbon Targets + demands for natural resources / LEAN Principles (war on waste)
7. Change Management theory / principles
8. BIM Protocol / implementation within existing forms of contract / Model Delivery Plan / Employers Information Requirements
9. COBie structures and families / templates
10. BIM Data maturity principles
11. PAS1192: 3 Asset Information Modelling – keeping the model up to date during FM / Occupation.

12. Collaboration Tools – Adding specifications, technical booklets, O&M information into data fields for Assemblies, Elements and Materials

13. Common Data Environment (CDE)- Adding U-Values / Carbon Footprint data into model components

14. Accessing data for de-construction using a variety of tools depending on vocational route

However, what this research [5] did not decide was the extent each of these elements relates to Civil Engineering's two specialist strands at Ulster: Structures and Highways. This paper seeks to fill this knowledge gap.

2. Research method

2.1 Definition of Survey sample

The BAF contains more than 30 academic representatives from a wide spectrum of UK and Ireland HEI's [3]. This documents list was used to determine that thirty-eight institutions were established as having members of staff acting as members of the BAF. As part of this research all 38 were contacted and twenty-four agreed to participate. BAF members had the requisite knowledge to complete the framework for BIM teaching and therefore had discipline specific skill.

2.2. Survey software used

The Limesurvey™ package supplied both the pilot and the full structured questionnaire. The software is a PHP frontend to a MYSQL database, with responses stored and analysed directly via the Limesurvey™ software for basic statistics and further using the Relative Importance Index (RII).

2.3. Survey validity and response statistics

Fifteen entirely completed responses were received with a 62.5 % response rate attained. Partially completed responses were ignored. The method of determining sample size devised by Krejcie and Morgan (1970) [6] required all the HEIs be contacted for validity. Rubin and Babbie (2009) [7] state a minimum response rate of 50 %. With 15 responses received, subsequent analysis met this criterion.

2.4 Analysis Techniques Used

The Likert scale used for both the Highways strand (denoted H) and the Structures stand (Denoted S) was '5 Extremely Relevant', '4 Very Relevant', '3 Moderately Relevant', '2 Slightly Relevant', and '1 Not at all Relevant'. This allowed the determination of the relevance of each of the topics in Section 1.3.

Comparisons between the specialisms were ranked and analysed using the Relative Importance Index (RII) Formula. RII is defined as:

$$\textit{Relative Importance Index}(RII) = \frac{\sum W}{A\,x\,N}\ (0 \leq index \leq 1)$$

Where: **W** is the weighting given to each element by the respondents -'5 Extremely Relevant', '4 Very Relevant', '3 Moderately Relevant', '2 Slightly Relevant', and '1 Not at all Relevant';

A is the highest weight; and

N is the total number of respondents.

The closer the result is to 1 the more important it is.

2.5. Expertise of the participants in BIM

The UK Government uses the Bew and Richards Triangle, level 0 – 3, to measure BIM expertise [1]. The BIM Industry Working Group (2011) [8] define these levels of BIM:

Level 0 *– Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely exchange mechanism.*

Level 1 *– Managed CAD in 2 or 3D format using BS1192: 2007 with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data managed by standalone finance and cost management packages with no integration.*

Level 2 *– Managed 3D environment held in separate discipline "BIM" tools with attached data. Commercial data managed by an ERP. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as "pBIM" (proprietary). The approach may utilise 4D programme data and 5D cost elements as well as feed operational systems.*

Level 3 *– Fully open process and data integration enabled by web services compliant with emerging IFC / IFD standards, managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes*

The UK Government requires level 2 on all its contracts by 1st April 2016 [1]. The survey examined the experience and skill level of academics on the BAF. Findings are in Table 1.

Table 1. Level of Academic Experience

Level of Experience by Academics on the Bew and Richards Scale		
Answer	**Count**	**Percentage**
Level 0	0	0 %
Level 1	1	7 %
Level 2	9	60 %
Level 3	5	33 %
No answer	0	0 %

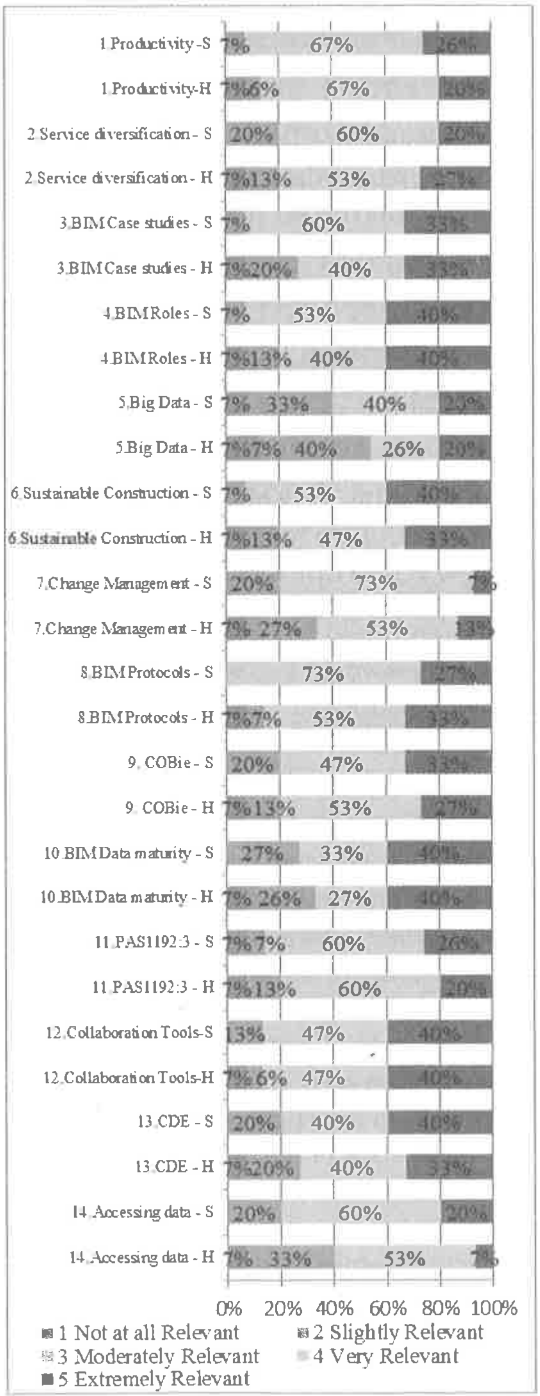
Table 1 indicates that the majority of the BAF have already got experience at level 2 which is the Government required level. This equated to sixty percent (60 %) of the responses, with another third (33 %) having experience and functioning effectively above this level. Only one respondent did not have experience to meet Level 2 (7 %). The capacity of teaching experience to operate, at or above the required level, means that those responding were capable of contributing knowledge and provide a good student experience. Table 1 demonstrates that Level 2 and above is being taught by most HEI's. It further indicates that those responding to the questionnaire have the requisite capacity to decide the content and importance of each of the BIM topics to both the structures and highways strands.

3. Findings on BIM

3.1. Final Year Students Specialising in Highways

The analysis of the topics shown in Table 2 (for Highways students denoted H) identified the following as 'Extremely relevant': 4 BIM roles (40 %), 10 BIM data maturity principles (40 %) and 12 Collaboration tools (40 %). The most important of these on a combination of 'extremely and very relevant' percentages are: 12 Collaboration aspects followed by 8 BIM protocols required for collaboration. Therefore this supports previous research on the drivers for BIM which concluded that Collaboration is the most important benefit of BIM [9].

Table 2. Importance of BIM topics
S= Structures & H= Highways The numbers match those in Section 1.3



The top two items of content considered 'Very relevant' are *1 Productivity improvements for BIM* (67 %), and *11 PAS 1192: 3* (60 %). *2 Service diversification, 7 Change Management theory, 8 BIM protocol, 9 COBie structures* and *14 accessing data for de-construction* were also deemed 'Very relevant' with 53 %.

Strangely the issue of '*5 Big Data*' relating to Highways was ranked as one of the lowest items with 54 % considering it moderate or lower. This was originally considered as one of the big issues for BIM teaching. Companies such as ARUP are very active in trying to interpret big data reporting on Road Surfacing and items such as Road Bridges. This merits further research.

3.2. Final Year Students Specialising in Structures

The analysis of the topics shown in Table 2 (for Structures students denoted S) identified the following as 'Extremely relevant' with 40 %: *4 BIM roles, 6 Sustainable construction, 10 BIM data maturity principles, 12 Collaboration tools* and *13 Common data environment.*

Other content acknowledged as 'Very relevant' includes *7 Change Management theory* and *8 BIM protocols* (73 %), *1 Productivity improvements for BIM* (67 %), *2 Service diversification* (60 %), *3 BIM case study* (60 %), *11 PAS 1192: 3* (60 %), and *14 accessing data for de-construction* (60 %).

3.3. Comparative Analysis between needs for Specialists in Highways and Structures

This section used the RII formula to determine the importance of each topic. It can be seen from the RII values of all 14 factors in Table 3 that in all cases BIM is more important to the structures students than the highways students.

The closer RII is to 1, the more important the result. Table 3 shows that the biggest discrepancy between the Highways and Structures topics relate to the following: *Accessing data for de-construction using a variety of tools depending on vocational route* (Difference 0.094), and *Sustainable Construction Principles and Carbon Targets and demands for natural resources / LEAN Principles (war on waste)* and *BIM Case study evidence from early adopters* (Difference 0.068 jointly).

Deconstruction of projects in the Highways sector through reuse of materials has the potential to save up to 0.5 % of the overall cost of the scheme [9]. However, the UK Government Construction Strategy [1] requests overall savings of up to 20 %. Therefore respondents have recognised the greater potential for savings through recycling in structural projects in rating the differences in the top two topics.

The BIM case study result is more difficult to explain. One possibility is that there were many more early adopters in the structures field than highways and therefore fewer case studies exist.

However, on the other side of this argument to ensure that the deadline for BIM adoption is met, which covers all fields of construction, these case studies should be used to ensure that the Highways sector is well prepared for the deadline.

Service Diversification (Difference 0.014) and *Collaboration* (Difference 0.028) are the results that are closest together. This is expected as both are issues that affect highways and structures almost equally.

4. Conclusions

Building Information Modelling (BIM) teaching is a relatively new subject. It has been implemented in a piecemeal way to meet the needs of graduates entering industry. The BAF has stipulated the various impacts embedding the teaching of BIM into the curriculum will have. Built on this the work of McLernon et al (2014) [5] produced a list of final year topics that should be taught as part of the BIM syllabus. This work did not stipulate the relevance to the various strands in Civil Engineering but was of a general nature.

This current work looks at the differences between Civil Engineering courses specialising in structures and highways. The findings show that the content contained in McLernon et al (2014) [5] was relevant to both disciplines.

However, the comparison between the two through the RII of each factor showed it was less important to those of a highways speciality. The findings also showed the elements that were extremely applicable to both streams were *4 BIM roles, 10 BIM data maturity principles*, and *12 Collaboration tools*. The results show that these should be the core elements concentrated on during the teaching of BIM in Civil Engineering Courses. The ranking of these aspects in Table 3 can be used to determine the importance of each factor in the delivery of the two specialisms.

Subjects such as *Big Data* and *Change Management theory* were considered to be lowest in priority for teaching in both areas. Therefore, these should be covered but not in as much depth as the other topics.

Table 3. Comparison of the Importance of BIM topics to Highways and Structures specialists

	Highways			Structures			Overall	
	ΣW	RII	Rank	ΣW	RII	Rank	Ave. RII	OA Rank
Collaboration Tools – Adding specifications, technical booklets, O&M information into data fields for Assemblies, Elements and Materials	61.95	0.826	1	64.05	0.854	3	0.84	1
BIM Roles (BIM Execution Plans, Roles, Responsibilities, Zoning Strategy, Federation, Deliverables, Data Drops)	60.9	0.812	2	64.95	0.866	1	0.839	2
Sustainable Construction Principles + Carbon Targets + demands for natural resources / LEAN Principles (war on waste)	59.85	0.798	4	64.95	0.866	1	0.832	3
BIM Protocol / implementation within existing forms of contract / Model Delivery Plan / Employers Information Requirements	60.75	0.81	3	64.05	0.854	3	0.832	3
BIM Case study evidence from early adopters	58.8	0.784	9	63.9	0.852	5	0.818	5
Common Data Environment – Adding U-Values / Carbon Footprint data into model components	58.8	0.784	9	63	0.84	6	0.812	6
Productivity improvements from BIM	58.95	0.786	5	62.85	0.838	7	0.812	6
COBie structures and families / templates	58.95	0.786	5	61.95	0.826	8	0.806	8
BIM Data maturity principles	58.95	0.786	5	61.95	0.826	8	0.806	8
Service diversification as a result of BIM	58.95	0.786	5	60	0.8	11	0.793	10

M topics
ts

tures		Overall	
II	Rank	Ave. RII	OA Rank
54	3	0.84	1
66	1	0.839	2
66	1	0.832	3
54	3	0.832	3
52	5	0.818	5
84	6	0.812	6
38	7	0.812	6
26	8	0.806	8
26	8	0.806	8
.8	11	0.793	10

PAS1192: 3 Asset Information Modelling – keeping the model up to date during FM / Occupation.	57.9	0.772	11	60.75	0.81	10	0.791	11
Accessing data for de-construction using a variety of tools depending on vocational route	52.95	0.706	13	60	0.8	11	0.753	12
Change Management theory / principles	54.75	0.73	12	58.05	0.774	13	0.752	13
Big Data – informing design – evidence based design	51.75	0.69	14	55.95	0.746	14	0.718	14

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